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The Landers Earthquake, 28 June 1992: Seeing California Move with GPS Satellites

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Imperceptible to human senses, California continues to deform every day at a rate comparable to the growth of fingernails. Convection in the mantle under the **Earth's** solid crust forces continental-size "tectonic plates" to move slowly **in** different directions. Where plates meet, the motion between them is accommodated by slow deformation; but when the crust is no longer strong enough to withstand the stress buildup, it breaks as an earthquake at weak points we call "faults."

The boundary of the Pacific and North American plate **runs** right through California, as evidenced by a swath of **faults**. One such fault broke near the town of Landers on 28 June 1992, producing a magnitude 7.5 earthquake. A series of ruptures tore over 70 km through the **Earth's** crust in a matter of seconds, producing destructive seismic waves as the **crustal** stress was released. Reacting to the sharp reduction in stress, southern California rearranged itself, like a taught elastic sheet that is torn in the middle.

Using a **global** network of ground-based receivers to track ranging signals from the 24-satellite Global Positioning System (**GPS**), geophysicists can now measure distances across North America with a precision of a few millimeter. The Permanent GPS Geodetic Array (**PGGA**) has been operating in California since spring 1990 as a collaborative project involving the Jet Propulsion **Laboratory**, the Scripps Institution of Oceanography, the **Massachusetts** Institute of Technology, and several other universities and agencies. Recently before the Landers earthquake occurred, a global network of GPS receivers had become fully operational (under the auspices of **IGS**, the International **GPS** Service for **Geodynamics**). This was fortunate, since it provided a stable "reference frame," which allowed us to accurately determine the positions of the GPS satellites

and observe the motion of the California **PGGA** with respect to the rest of the world.

Investigators at the above mentioned **institutions** performed independent analyses using different software ("**GIPSY**" and "**GAMIT**") to estimate the motion of receivers in the California **PGGA**. The results are in excellent agreement, and are shown in the accompanying figure along with contour lines depicting the modeled deformation. The site **JPLM** in Pasadena is shown moving approximately in a northwesterly direction by 1 cm. We saw a slight but significant disparity between the results and earlier models of the earthquake that were based on seismological and field observations, which allowed us to improve our model of the rupture details. This illustrates the potential for future interdisciplinary research that involves seismology and GPS geodesy,

Although unexpected, the **Landers** earthquake provided an early demonstration of the utility and accuracy of permanent GPS **networks** in geophysical research. The operation and processing of such networks is now almost completely automatic. Permanent GPS **networks** are quickly becoming recognized as an economically attractive research option. Regional GPS networks similar to the California **PGGA** have been or will soon be implemented in Japan, Canada, Norway, Sweden, and Australia.

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Figure attached.

Figure Caption:

Observed (solid arrows) and modeled (blank arrows) displacements at four of the PGGA stations in southern California due to the Landers and Big Bear earthquakes of 28 June 1992. We show the displacements and 95% confidence ellipses computed by Bock *et al.* (shaded ellipses) and Blewitt *et al.* (unshaded ellipses). The observed displacements are with respect to a global reference frame and, therefore, indicate absolute displacements of the California sites. The contours for displacement magnitude and the computed displacements are based on an elastic halfspace assumption for the behavior of the Earth's crust (all units mm). The surface trace of the Landers rupture is indicated by a heavy line and for the Big Bear earthquake by a dashed line. Figure adapted from Bock *et al.* [1993].

